Millivac
Hushed Transistor
Amplifier
VS-64A

OPERATING INSTRUCTIONS
FOR
HUSHED TRANSISTOR PRE-AMPLIFIER TYPE VS-64A

Introduction: The VS-64 A Hushed Transistor Pre-Amplifier is a highly sensitive pre-amplifier for oscilloscopes. It excels other amplifiers by having an exceptionally low noise voltage, referred to its input terminals. This noise voltage increases as the generator resistance, or source impedance to which the amplifier is connected, is increased. The relationship between noise voltage, referred to the input terminals, and generator resistance is shown on page 2 of the VS-63 A/VS-64 A bulletin at the end of this instruction book. Additional information concerning the VS-64A amplifier and complete performance specifications may also be found in this bulletin.

The amplifier can be operated with two different input impedances, 10 K and 100 K. The 10 K input impedance is obtained by feeding signals directly into the first amplifying transistor, which operates in a so-called "hushed" condition. The actual input impedance of this transistor is approximately 1 K, but it is increased through heavy negative feedback. The 100 K input impedance is obtained by connecting in series with the input circuit of the amplifier an emitter-follower which, by virtue of its comparatively high transconductance (25,000) and large emitter load resistance (6 K), possesses such a high negative feedback ratio that the original 1 K impedance of the transistor is increased to 100 K.

Description of Operation: The amplifier is equipped with two interchangeable shielded clip leads, one for its input, and one for its output.

To make some preliminary tests for the purpose of verifying the proper functioning of the amplifier and getting acquainted with microvolt-level amplification, connect the amplifier's output to an oscilloscope having a sensitivity of at least 100 mV peak-to-peak for full screen deflection. A typical suitable scope in general use today is the Du Mont 304. The scope should be set for a 60 cps sweep rate and should be synchronized by the power line. Do not synchronize the scope internally since a random sweep frequency would make it impossible to distinguish between accidental hum pick-up and amplifier noise. Some scopes are equipped with a 60 cps calibrator. In this case, the calibration signal should temporarily be used for the purpose of adjusting the sweep frequency and line sync until a single steady 60 cps wave appears on the screen.

Each amplifier is shipped with a 1000:1 test divider consisting of a 10 K and a 10 ohm resistor. This test divider should now be plugged into the input receptacle of the VS-64A amplifier and the other shielded clip lead should then be connected to an audio frequency signal generator which delivers a 1 mV, 360 cps signal. Since the scope is being swept at a rate of 60 cps, six full waves will therefore appear on the screen. If they drift from left to right or in the opposite direction, this would indicate that the frequency calibration of the generator is not quite accurate and the six waves should be brought to a standstill by slightly changing the frequency setting of the generator (not by making adjustments with the sweep or sync controls of the scope).

The gain selector switch of the VS-64A amplifier should be set to 80 DB and the input impedance selector should be turned to the 10 K position. The upper bandpass switch should be set to 180 KC, which is fully clockwise, and the lower bandpass switch should be turned to the 2 cps position, also fully clockwise.

Check the battery voltage on the voltmeter. It should be at least 5.4 V.

The voltage of the signal being fed into the amplifier should be monitored with a suitable VTVM, such as the Ballantine 300 or the Millivac MV-12B. The output of the generator should be adjusted for 1 mV RMS at 360 cps. The 1000:1 input divider reduces this voltage to 1 uV RMS.

Since the gain of the amplifier in the 80 DB position is approximately 10,000, it will put out a 10 mV RMS signal, equivalent to 28 mV peak-to-peak and therefore approximately 28% of full screen sensitivity of the scope if the sensitivity of the scope is 100 mV peak-to-peak and if it is turned up to its maximum sensitivity.

The six waves representing the 1 uV RMS signal being fed into the amplifier will exhibit a certain amount of noise (grass). With both bandpass switches turned up fully as described, the noise should be approximately 650 to 750 muV RMS, referred to the input. This is at least 20 DB less noise than a conventional vacuum tube amplifier would exhibit under identical conditions.

Noise can be reduced by cutting down the band width of the amplifier. The relationship between noise voltage, referred to the input terminals, and various positions of the upper and lower bandpass limiting switches is given in a table on page 2 of the VS-63A/64A bulletin attached to the end of this

instruction book. A few settings should be tried out. It should be noted that particularly when turning the upper bandpass switch down toward the low kilocycle region, most of the grass in the 1 uV signal trace will disappear.

In many cases a test of this kind will reveal the presence of a certain amount of hum appearing on the scope. It may be as high as 1 uV RMS, sometimes even more. The following causes for such hum pick-up have been found to be the most frequent ones:

(a) Location of the VS-64A amplifier in the immediate vicinity of a line-operated device such as a vacuum tube voltmeter, scope or signal generator, whose power transformer radiates a rather powerful hum-field which interferes with the VS-64A amplifier's input signal. Shifting the amplifier to a more remote position and rotating it in a direction in which hum pick-up is minimized usually eliminates this trouble.

(b) The monitoring vacuum tube voltmeter can, on occasions, feed a hum signal into the amplifier. This can be verified by disconnecting the VTVM altogether after it has served its purpose as a monitoring device for the signal generator voltage.

(c) Power lines below or above the test table, even if several yards away, have been recognized as major sources of magnetic hum-fields.

(d) Some generators are not equipped with suitable attenuators to put out signals as small as 1 mV. Quite often decade boxes, microvolters and other attenuators are then used in order to

attenuate the output of the generator. Most of these attenuators represent large hum picking-up loops and on occasions they are not even electrostatically shielded. Therefore, they can be the cause of very large hum signals.

(e) On rare occasions leaky power transformers in either the generator or the scope can cause large hum currents in the common ground system.

(f) Poor ground connections between the amplifier and the scope or more so between the amplifier and the generator can create large hum signals.

As a general means of providing a comparatively clean and hum-free 1 mV signal, a simple divider, made out of two carbon resistors can be provided. It consists of a 10 K and a 10 ohm resistor which should be soldered together as closely as possible and their leads should be as short as possible. The unshielded ends of the shielded clip-lead should then be twisted together to minimize hum pick-up and they should be clipped across the 10 ohm resistor, the black clip being attached to the grounded end of the 10 ohm resistor and the red one to the junction between the 10 ohm and the 10 K resistor.

After these preliminary tests have been carried out with the amplifier being switched to its 80 DB range, they should be repeated on other ranges having less gain, with correspondingly larger signals. Then, as operating conditions, reasonably free from hum-interference, have been established, the amplifier may now be used for the actual amplification of low-level signals in the microvolt region. To do this, the 1000:1 test divider should

should be removed and the input lead should be plugged directly into the input terminals of the amplifier.

It is obvious that after the removal of the 1000:1 test divider the amplifier is 1000 times more sensitive against interference by hum-fields and radio frequency interference than before. Radio-interference hardly requires any special consideration as long as the 1000:1 test divider is used because the divider is well shielded. Now, however, after removal of the divider this protection is no longer available and the input circuit must be shielded carefully against both hum and radio frequency interference. Careful shielding by conventional means, such as operation in a shielded room, mounting the test equipment which furnishes the AC signal to be observed in a shielded box, etc. will provide adequate protection. The user will soon become acquainted with the high susceptibility of the amplifier's input circuit to interference signals which is an unavoidable attribute to the extremely high sensitivity of the VS-64A amplifier.

Description of Circuit: Drawing VS-1067 shows the circuit diagram of the VS-64A amplifier.

The amplifiers consist of two cascaded 4-stage units, T_2, T_3, T_4, T_5, and T_6, T_7, T_8, and T_9. These units, one being the pre-amplifier and the other the main amplifier are interconnected by a 4-step output divider for the pre-amplifier, R28, R29, R30 and R31. In the maximum gain position (80 db) the full output of the pre-amplifier is transferred to the input of the main amplifier. In the 70 db position the output of the main amplifier is attenuated by 10 db, in the 60 db position by 20 db, and in the 50 position, by 30 db. On the next four lower gain positions (40 db-10 db) the main

amplifier is disconnected altogether, only the pre-amplifier being used. At 40 db the full output of the pre-amplifier is once more selected to be passed to the output terminals, at 30 db, 10 db less, at 20 db, 20 db less, and at 10 db, 30 db less. It will be noted that the output divider R28-R31 of the pre-amplifier has an additional resistor R32 in series which drops the actual signal voltage at the collector of output transistor T_5 by more than 50%. This seeming waste of amplification is necessary in order to establish a de-coupling link between output transistor T_5 of the pre-amplifier and input transistor T_6 of the main amplifier when the instrument is operating in its 80 db position. Without such de-coupling an undesirable change of frequency response between the 80 db range and the other ranges would occur which is caused by the "echo-effect" due to transit, re-transit and re-re-transit of the signal in the collector junctions of the two transistors involved. This strange phenomenon is still being studied at present. The de-coupling system described has been found to be an effective counter-measure against this undesirable phenomenon.

The four transistors in each amplifier are directly coupled, which is particularly advantageous in a hushed transistor amplifier because the voltage drop across the collector junction in a transistor, operating in hushed condition, is essentially zero. In a hushed direct-coupled amplifier, it is therefore (contrary to direct-coupled vacuum tube amplifiers) not necessary to provide the customary "DC pedestals" for the emitter (or cathode) to make such direct coupling possible. It will be noted that the first three emitters in each amplifier are directly inter-connected while the fourth emitter has the customary resistor in the emitter circuit to

provide the usual DC pedestal required for direct-coupling. The reason for this arrangement is that the first two transistors operate in hushed condition which means that, for instance, in the pre-amplifier the base and collector of T2 and the base and collector of T3 all have essentially the same potential to ground. It is in the general order of -150 mV. T4 is not completely hushed and has a substantially higher collector voltage, in the general order of-800 mV while T5 is even less hushed, having a collector voltage in the general order of-2.8 V.

While each of the two amplifiers is directly coupled within itself, both are in reality AC amplifiers having capacitive input and output coupling and being equipped with a powerful DC feedback circuit (R13 and R6 in the pre-amplifier and R25 and R19 in the main amplifier). The DC feedback is taken from the emitter of the output transistor and is fed into the base of the input transistor. Since signals are in phase-opposition at these two points a vigorous DC self-biasing action is produced which counteracts effectively bias-drifts liable to occur as the result of room temperature changes. Each DC feedback path has a by-pass condenser (C3 in the pre-amplifier and C12 in the main amplifier) which absorbs the AC component of the output signal thereby preventing negative feedback of the AC output signal into the base of the input transistor.

A second feedback loop handling both AC and DC signals and serving the dual purpose of gain stabilization and bandpass extension is provided by the common emitter resistor for the first three transistors in each amplifier (R9 in the pre-amplifier and R21 in the main amplifier). Each of these common emitter resistors, in reality, acts in two different ways.

Due to phase-inversion between subsequent stages, the common emitter resistor has a slight regenerative effect between neighbor-transistors, for instance, between T_2 and T_3 or T_3 and T_4, but it has an overruling degenerative effect upon the first three stages together. The local regenerative effect described raises local stage gain and therefore indirectly increases the overall degeneration since the latter is directly proportional to local stage gain. The gain of the fourth transistor (T_5 in the pre-amplifier and T_9 in the main amplifier) is stabilized by the large emitter resistor in that stage.

Each amplifier is equipped with frequency-response correcting networks. They prevent an undesirable rise of gain near the upper cut-off point of the pass-band due to phase rotation. Trimmer C 14 and adjustable control R10 provide both an amplitude reduction and phase correction in the region of the bandpass in which such an undesirable rise would otherwise occur. Trimmer C4 and fixed condenser C5 serve a similar purpose. The main amplifier has equivalent trimmers and controls in the corresponding sections of its circuit. The two trimmers and the control in each amplifier are carefully adjusted in each instrument to give the desired frequency response before the VS-64A amplifier is shipped. They normally do not require resetting and should be touched only if, after a change of transistors, particularly input transistors, this should be found to be necessary. When making such an adjustment, the bandpass controls should be set for full bandwidth (2 cps-180 KC). The main amplifier should be adjusted so that its response is flat within 0.5 db up to 180 KC, while the pre-amplifier should be adjusted to have a 3 db fall-off at 180 KC when both amplifiers are cascaded (50-80 db).

Each amplifier is also equipped with a DC centering control (R4 in the pre-amplifier and R16 in the main amplifier). It supplies an adjustable bias current into the base of the input transistor of each amplifier and should be set for -2.8V DC at the collector of the output transistor (T_5 in the pre-amplifier and T_9 in the main amplifier). Proper setting of this voltage is important to avoid overloading or clipping of either amplifier, particularly on the 50 db and on the 10 db ranges. The collector voltage should be measured with a vacuum tube voltmeter. It can also be adjusted by observing the behavior of the amplifier on either the 50 db or the 10 db range, preferably on both, the adjustment being made in such manner that nearly symmetrical clipping occurs on the upper and lower crest of a low frequency sine wave (such as 400 cps) being fed into amplifier.

The pre-amplifier chassis has an additional transistor T_1 which is an emitter-follower. Its performance resembles the customary cathode-follower in a vacuum tube amplifier except that its conversion efficiency is substantially higher than in the conventional cathode-follower. The emitter-follower is used only when the amplifier is switched to its 100 K input impedance position. In this position the signal passes first into the emitter follower and then into the pre-amplifier, the emitter follower having a 98 to 99% voltage conversion efficiency, its input impedance being approximately 100 K and its dynamic output impedance usually being below 200 ohms.

The emitter follower is not hushed since it has a collector junction voltage in the order of 3 V. However, the high noise developed in its

collector junction is nearly completely being de-amplified in the transistor itself in view of its high conversion efficiency, in other words, since by itself it possesses a feedback ratio in the order of 40 db. The small remainder of noise which is being passed on to the subsequent preamplifier causes the VS-64A amplifier to be slightly more noisy when used with 100 K input impedance. However, there are many applications in which the higher noise will be preferred in view of the higher input impedance than the lower noise in the 10 K position where input impedance is smaller.

The VS-64A amplifier is equipped with two bandpass filters, one limiting the upper end of the frequency response and the other the lower end. These two filters are located near the output terminals of the circuit and consist of simple R/C networks. They are self-explanatory except that there is a further emitter-follower τ 10 between the low frequency limiter and the high frequency limiter. It acts as an impedance converter and prevents undesirable inter-action between the two filters.

Power is supplied to the instrument from two parallel 6V batteries (Burgess FP1) which have a minimum life of 150 hours and should be replaced as soon as the monitoring voltmeter on the panel indicates a voltage lower than 5.4. The monitoring voltmeter also replaces the customary pilot light in this amplifier which is not being provided since it would draw more power than the total of 10 transistors and would unnecessarily shorten battery life.

GUARANTEE

THE VS-64A AMPLIFIER IS GUARANTEED BY US FOR A PERIOD OF ONE YEAR FROM THE DATE OF SHIPMENT

AGAINST DEFECTIVE COMPONENTS AND FAULTY WORKMANSHIP.

EXCLUDED IN THIS GUARANTEE ARE ALL DEFECTS CAUSED BY ABUSE OF THE AMPLIFIER, PARTICULARLY SUCH ABUSE WHICH RESULTS IN BURNING OUT OF TRANSISTORS. WITH PROPER HANDLING, REPLACEMENT OF TRANSISTORS IS UNNECESSARY FOR MANY YEARS.

IF AN AMPLIFIER SHOULD BE CONSIDERED TO BE DEFECTIVE, IT SHOULD NOT BE SENT IN TO US FOR REPAIR WITHOUT WRITTEN AUTHORIZATION. PLEASE STATE IN YOUR REPORT THE NATURE OF THE COMPLAINT AND WHETHER ANY COMPONENTS IN THE INSTRUMENT HAVE BEEN REPLACED IN AN EFFORT TO CORRECT THE TROUBLE.

TWO-WAY TRANSPORTATION CHARGES ARE TO BE BORNE BY THE CUSTOMER.

VOLKERS & SCHAFFER MFG. CO.
SCHENECTADY, NEW YORK

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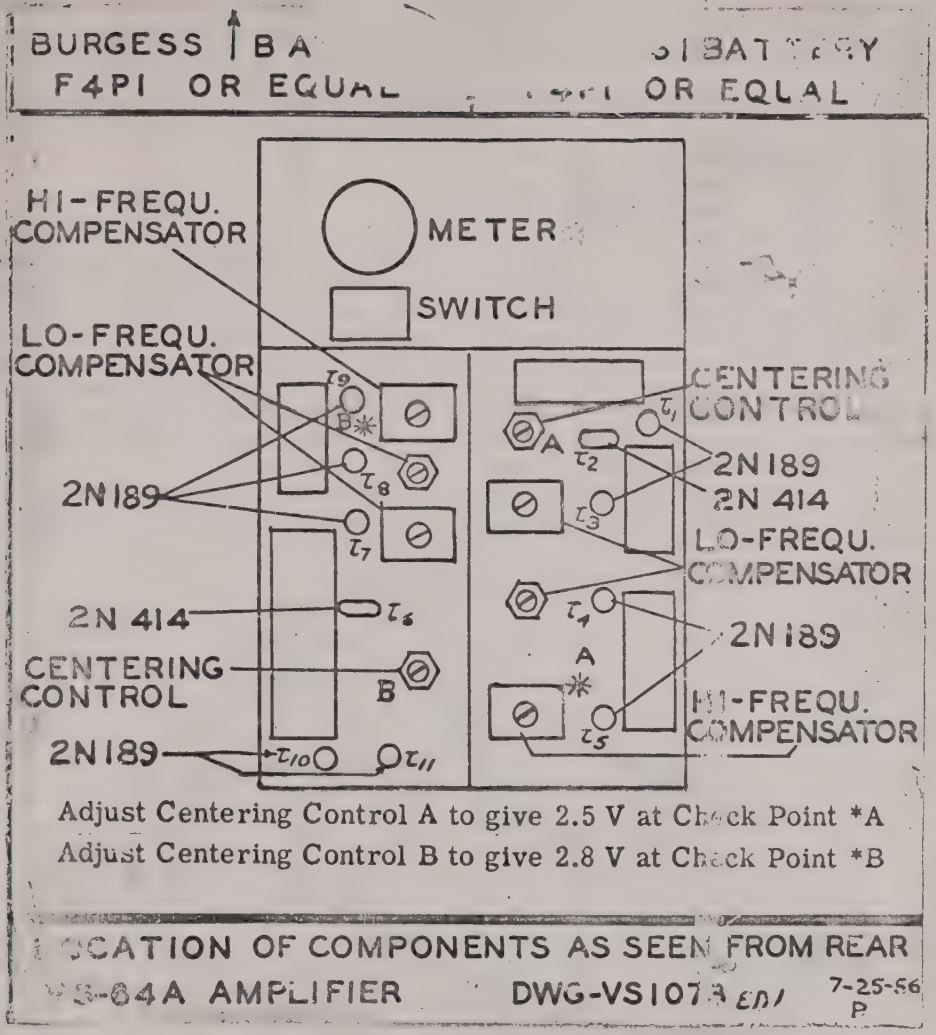
BURGESS BA
F4PI OR EQUAL
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Adjust Centering Control A to give 2.5 V at Check Point *A
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LOCATION OF COMPONENTS AS SEEN FROM REAR
VS-64A AMPLIFIER
DWG-VS107A
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VS-63A **ULTRA LOW NOISE** VS-64A

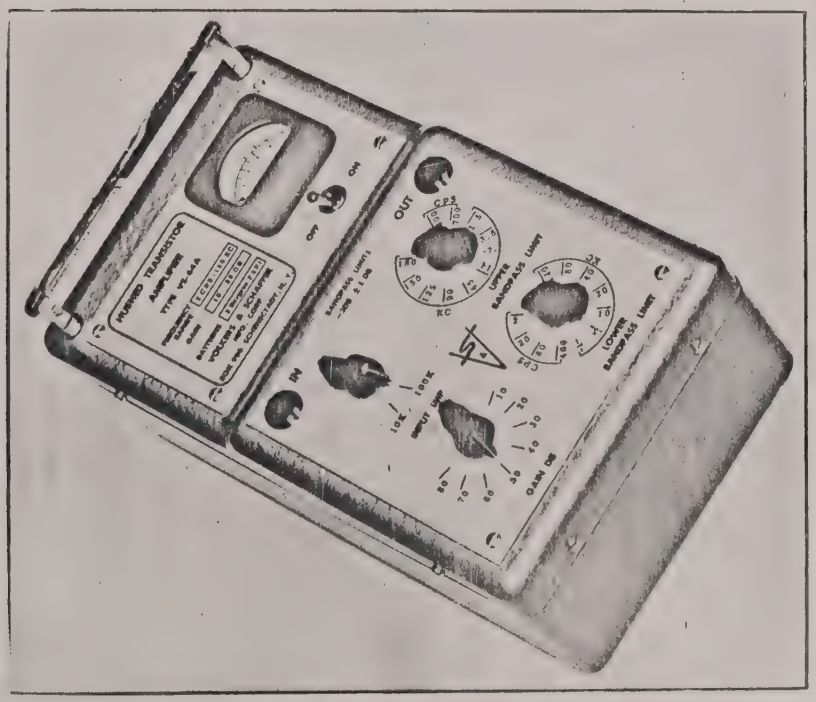
HUSHED TRANSISTOR PRE-AMPLIFIERS FOR DC AND AC

General

The discovery of the principle of "hushed transistor operation" by Dr. Walter K. Volkers, and Norman E. Pedersen, which was first disclosed in a lecture at the National Electronic Conference in Chicago in the Fall of 1955, came as a great surprise to most electronic engineers. Until then, transistors had always been considered unavoidably more noisy than vacuum tubes.

Hushed transistors operate with essentially zero or reversed collector junction voltage. This drastically reduces their collector noise and results in noise voltages, referred to the shorted input terminals, which are 20 to 30 db lower than those of the finest vacuum tubes.

In addition, hushed transistors, when used in a direct-coupled amplifier, exhibit substantially less DC drifts than vacuum tubes. Transistors do not have heated cathodes and are therefore entirely free from the main source of drifts in conventional direct-coupled vacuum tube amplifiers - - - cathode drifts. A direct-coupled hushed transistor amplifier therefore approaches the freedom from drift which would normally be expected from a chopper-stabilized DC amplifier.



VS-64A

HUSHED TRANSISTOR AMPLIFIER — AC

The new completely transistorized AC amplifier, Type VS-64A, is an improvement over our earlier hushed amplifiers which had both transistor and vacuum tube stages.

By equipping the VS-64A amplifier with high quality precision resistors, "extra noise" beyond pure thermal noise could be reduced still further below the already unusually low 0.5 uV RMS noise voltage within a 60 KC pass-band which our earlier models had. Two band-pass limiting switches make it possible to restrict noise still further by eliminating its components associated with an unwanted extension of the pass-band above or below the desired frequency range. The following tables show typical noise voltages referred to the shorted input with either the high frequency or

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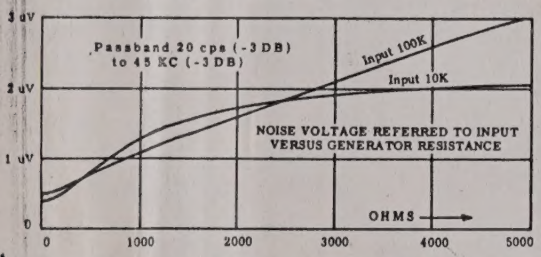
BOX 996, SCHENECTADY, N. Y.

the low frequency limiting switches in their various positions. They show that with a substantially restricted pass-band, noise voltages as low as 100 muV or lower can be expected.

UPPER FREQ. LIMIT		LOWER FREQ. LIMIT	
FREQUENCY	E NOISE INPUT SHORTED	FREQUENCY	E NOISE INPUT SHORTED
300 CPS	50×10^{-9} V	120 KC	350×10^{-9} V
700 CPS	62	80 KC	455
1.5 KC	75	40 KC	535
3.5 KC	98	20 KC	560
7 KC	125	10 KC	570
14 KC	155	5 KC	580
45 KC	300	1 KC	590
90 KC	445	400 CPS	600
125 KC	520	80 CPS	605
150 KC	555	20 CPS	615
180 KC	615	2 CPS	695
WITH LOWER LIMIT 20 CPS		WITH UPPER LIMIT 180 KC	

Noise voltage, referred to the input terminals, increases with source impedance. The relationship is shown in the two curves plotted below for 10 K and 100 K input impedance.



The gain of the VS-64A amplifier is adjustable in steps from 10 db to 80 db. This makes the amplifier a highly flexible laboratory instrument which can be used to increase the sensitivity of oscilloscopes or vacuum tube voltmeters, not only in cases where extreme sensitivity is desired but also if only a moderate sensitivity boost of 10 or 20 db is needed.

The input impedance of the VS-64A is adjustable in two steps, either 10 k or 100 k. With 10 k input impedance, the signal is fed directly into the base of the input transistor while in the 100 k position of the input impedance selector switch it is fed into the base of an emitter-follower (impedance converter). The emitter-follower increases noise slightly as shown in the more detailed specifications below.

VS-63A HUSHED TRANSISTOR AMPLIFIER — DC

This new and also completely transistorized amplifier is similar to the VS-64A AC amplifier, except that it amplifies DC signals. The main differences between these two amplifiers are: The input impedance is 1 k, in place of 10 k or 100 k. The gain is adjustable in three steps from 20 db to 60 db. Since this is a DC amplifier, only one band pass limiting switch is provided restricting the upper band pass limit (125 KC max.)

Most DC amplifiers available on the market today have the disadvantage of maintaining their inherent and unavoidable DC drifts when used as AC amplifiers. In the VS-63A, this weakness has been eliminated by providing a self-biasing circuit between input and output as soon as the amplifier is switched from DC to AC amplification. Another important advantage which the VS-63A offers in comparison with many other DC amplifiers is that its output DC voltage can be fully cancelled assuring ZERO-DC-IN/ZERO-DC-OUT performance. No external DC bucking source is therefore required.

DC drifts in the VS-63A are relatively small. They amount to approximately 50 uV per hour after an initial warm-up time of half an hour, providing room temperature is constant within two degrees. Further details will be found in the specifications below:

SPECIFICATIONS

TYPE VS-64A (AC-AMPLIFIER)

GAIN: 10 - 80 DB, plus/minus 1 DB, selectable in 10 DB steps.

FREQUENCY RESPONSE (including capacitive loading by amplifier's own shielded output lead, but exclusive additional capacitive loading): 3 DB down at 2 cps and 180 KC. - Amplifier has upper and lower band-pass limiting switches, each 11 positions, limiting frequency response as follows (with a 1 DB tolerance): Upper limits 180 KC, 150 KC, 125 KC 90 KC, 45 KC, 14 KC, 7 KC, 3.5 KC, 1.5 KC, 700 cps and 300 cps, lower limits 2 cps, 20 cps, 80 cps, 400 cps, 1 KC, 5 KC, 10 KC, 20 KC, 40 KC, 80 KC and 120 KC.

INPUT IMPEDANCE: selectable in 2 steps, 10 K or 100 K, the latter increasing noise with shorted input slightly.

OUTPUT IMPEDANCE: approx. 2 K.

MAXIMUM OUTPUT SIGNALS: 80, 70, 60, 50 and 40 DB ranges, 300 mV peak-to-peak, 30 DB range, 100 mV peak-to-peak, 20 DB range, 30 mV peak-to-peak and 10 DB range, 10 mV peak-to-peak. The 80 through 40 DB ranges will give sufficient output to drive Du Mont type 304 scopes to full screen deflection.

NOISE (with input shorted, 10 K input position): less than 450 muV RMS over a 60 KC pass-band, more with wider pass-band and less with lower pass-band. For relation between noise and pass-band see table in description, above. Noise voltage will not be more than 1.5 DB in excess of figures given in table above. - Noise Figure at 1 KC with optimum generator resistance (usually between 1 K and 2 K) 3 DB, tolerance plus/minus 1 DB (with 100 K input impedance).

DISTORTION (other than noise): 1% max. at 50 mV peak-to-peak output level, 2.5% max. at 100 mV level.

BATTERIES: 2 Burgess F4P1, minimum life 150 hrs.

ACCESSORIES: shielded input and output leads, 1000:1 ratio Input Test Divider (10 K/10 ohms, 3% tolerence).

DIMENSIONS: 7" wide, 12" deep, 5" high, including prop-up rail for scopes.

PRICE ..... $ 395.00

TYPE VS-63A (DC-AMPLIFIER)

GAIN: 20 - 60 DB, plus/minus 1 DB, selectable in 20 DB steps.

FREQUENCY RESPONSE (including capacitive loading by amplifier's own shielded output lead, but exclusive additional capacitive loading): 3 DB down at 125 KC. Amplifier has an upper-band pass limiting switch, 9 positions, limiting frequency response as follows (tolerance 1 DB): 125 KC, 90 KC, 45 KC, 14 KC, 7 KC, 3.5 KC, 1.5 KC, 700 cps and 300 cps.

INPUT IMPEDANCE: 1 K.

OUTPUT IMPEDANCE: Approx. 2 K.

MAXIMUM OUTPUT SIGNALS: 60 and 20 DB ranges, 100 mV peak-to-peak, 40 DB range, 10 mV peak-to-peak. Output of 60 and 20 DB ranges sufficient to drive Du Mont type 304 scopes to full screen deflection.

NOISE: (with input shorted): less than 600 muV RMS over a 60 KC pass-band, changing with wider or narrower pass-band as described for VS-64A. Noise Figure at 1 KC with optimum generator resistance 2.5 DB, tolerances plus/minus 0.8 DB.

DISTORTION, BATTERIES, ACCESSORIES AND DIMENSIONS: See VS-64A specifications, except 4 batteries instead of 2.

PRICE ..... $ 425.00

ACCORDION
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R-2507

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